MANAGING A DESCENT PROFILE

Last Updated: *6th December, 2016*

TheAirlinePilots.com

Flying a good descent profile is very important as descending early results in flying too long at low levels which reduces terrain clearance (increasing the chances of CFIT) apart from wasting fuel, while descending late results in unnecessary turns and high rates of descent which can lead to an unstabilized approach apart from making the passengers uncomfortable.

So what is the best option that neither makes you very low or high during your descent?

The Rule of 3

In aviation, the rule of three or "3:1 rule of descent" is that 3 miles of travel should be allowed for every 1,000 feet of descent. In the early days of aviation, few aircraft were pressurized. A pilot who descended rapidly would cause his passengers the discomfort of rapid pressure changes on their eardrums. Transport pilots adopted this formula to assure a slow, steady and comfortable descent for their passengers. Although rate of cabin pressurization change may be a consideration, in modern airplanes this is usually managed automatically and for an airliner a larger consideration is fuel economy.

An additional use of this rule-of-thumb is on final approach as the standard approach angle is 3° integrated into Instrument Landing Systems (ILS) and Visual Approach Slope Indicators (VASI) installed at many airports. Therefore, maintaining a 3° profile during the descent ensures a smooth transition from the descent to the approach phase in order to land within the touchdown zone of the runway.

A pilot must visualize flight path over the ground (in reference to the runway) as well as the vertical approach path e.g. if a pilot plans the approach to begin at 10 nm (a typical distance for an ILS) from the end of the runway, he should know what altitude above field elevation should the aircraft be when intercepting the final approach.

Let's take help of basic trigonometry to understand this:

Angle = 3°, Distance = 10 nm, Height = H.

Tan 3° = H / 10

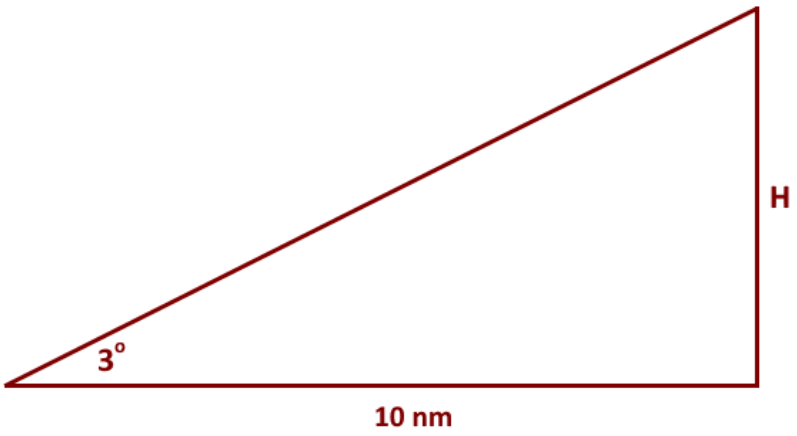
H = Tan 3° x 10

H = 0.052 x 10 = 0.52 nm

1 nm = 6076 feet

Height = 0.52 x 6076 = 3159 feet

So the pilot should maneuver the aircraft so as to turn final approach 10 nm from the runway at an altitude of 3159 feet above airfield elevation. The purpose of this example is to ensure that the pilot understands the relationship of altitude and distance when flying in a 3-dimensional environment.



Pilots do not fly aircraft with calculators in their laps, therefore in order to fly the correct descent profile, we need to answer the following questions:

1) How to calculate the point of descent i.e. TOD that matches a 3º profile?

2) How to determine the required rate of descent once TOD is reached?

3) How to maintain a 3º profile during descent?

One answer to all of the above is FMC's VNAV function, but to get the concept right and for a better understanding (just in case the VNAV is not there or misbehaves) let's do it manually.

Before answering the above questions, following two things involved in flying a correct descent profile need to be understood correctly:

- Vertical Distance
- Horizontal Distance

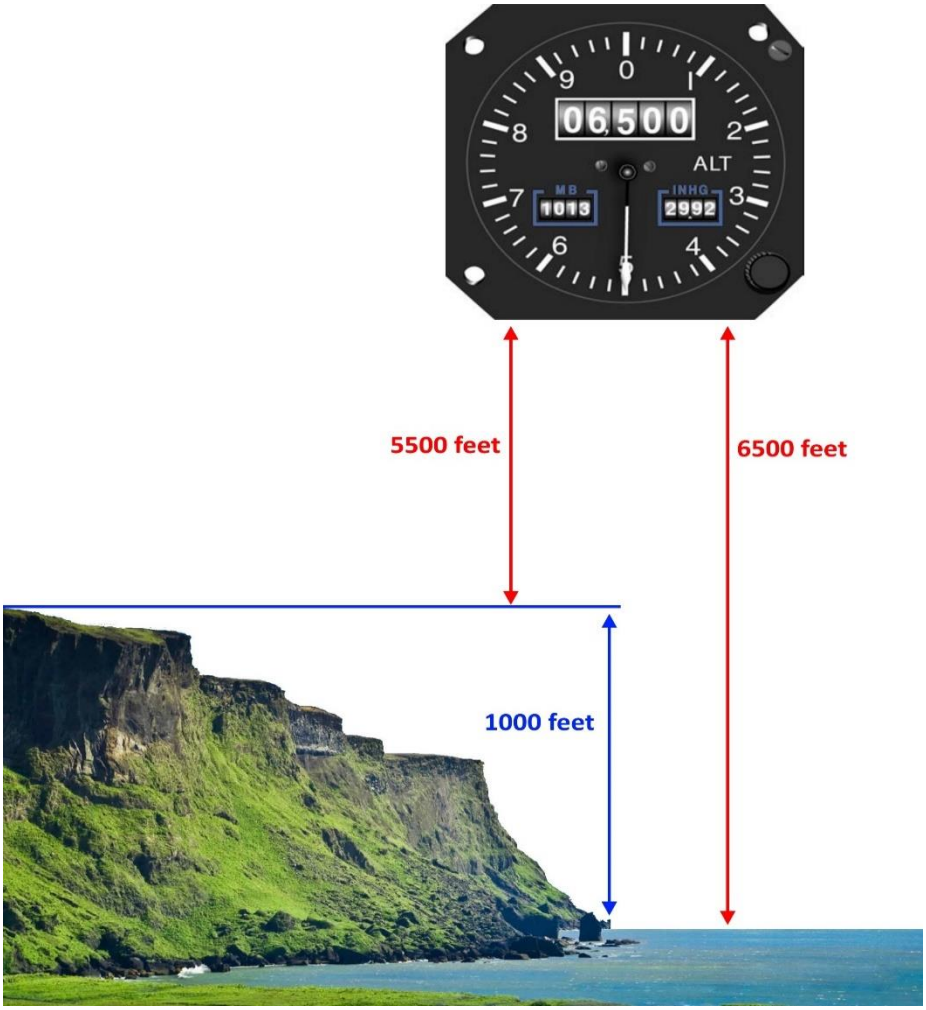
Vertical Distance

This is the vertical distance between the aircraft and the landing field elevation measured in terms of height. The basic instrument in the airplane to measure this is the pressure altimeter. It depends how you use the altimeter. If you set the landing field pressure on it (QFE) it will give you the height of the airplane above the field. On the other hand, if you set sea level pressure (QNH) then it will give you the height of the airplane above the sea.

To fly a correct descent profile, we are interested in height above the landing field and not sea so we have to make sure that the height which we are using in our calculations is correct. Generally, QNH is used at most places, that means our altimeter will be showing height above sea. If the landing field is at sea level, then good enough but if it is above that then we will have to resolve this discrepancy to get the height above the landing field instead of sea.

So in the example shown on the right if you want to fly 6500 feet above the hill, then what should your altimeter show?

If you are flying on QNH, the altimeter should show 7500 feet because 6500 feet above a hill which itself is 1000 feet makes 7500 feet.



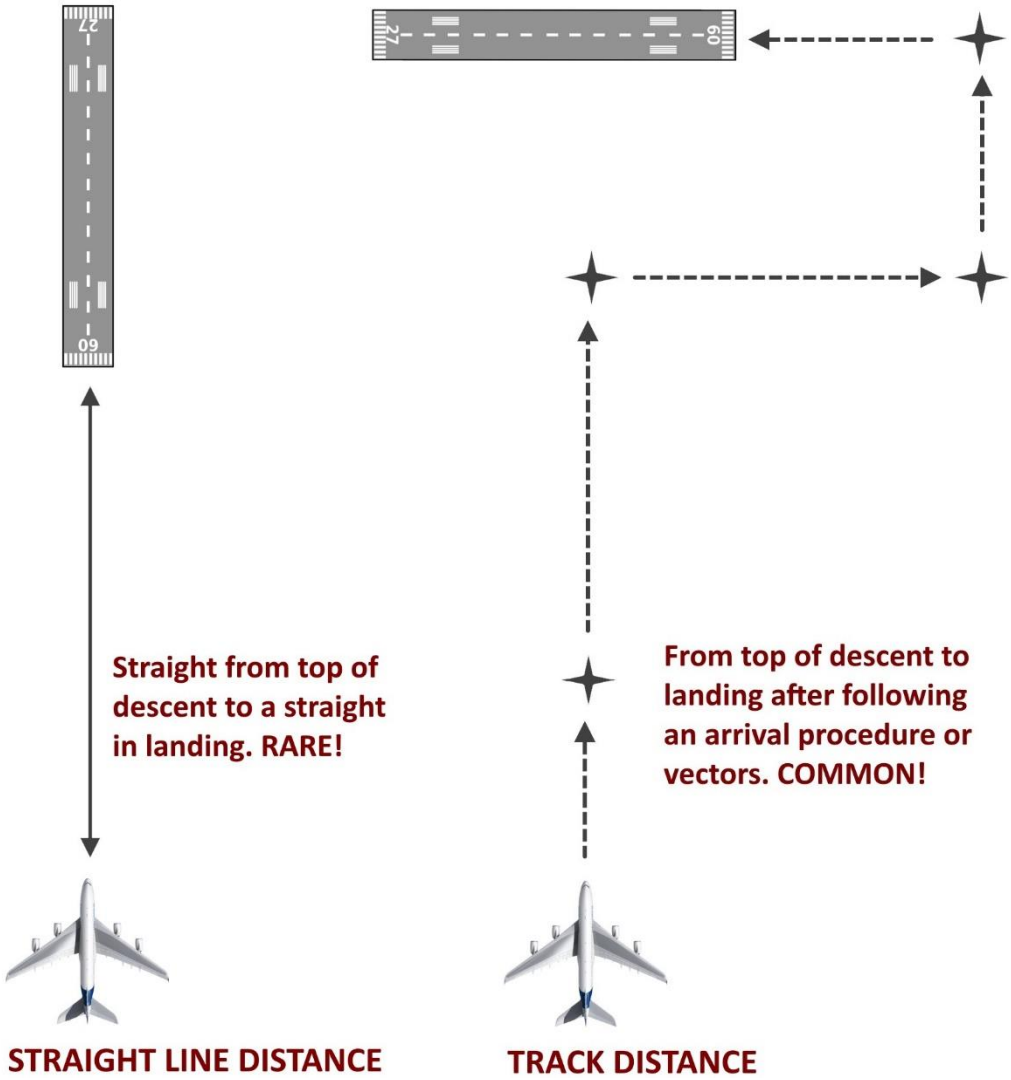
Horizontal Distance

This is the horizontal distance between the aircraft and the landing field. Like height (QFE and QNH) this can be of two types i.e. a straight line distance or track distance.

A straight line distance is the distance between the airplane and the landing field, regardless of the path the airplane follows to reach its destination. On the other hand, the track distance is the distance of the path that an airplane follows while reaching its destination i.e. the landing field.

Just like all fields are not located at sea level, descent and approach to landing path may not always be a straight line (and mostly will not be).

In order to fly a correct descent profile, we are interested in the track distance and not the straight line distance, so we have to make sure that the horizontal distance which we are using in our calculations is correct.



Coming back to the questions:

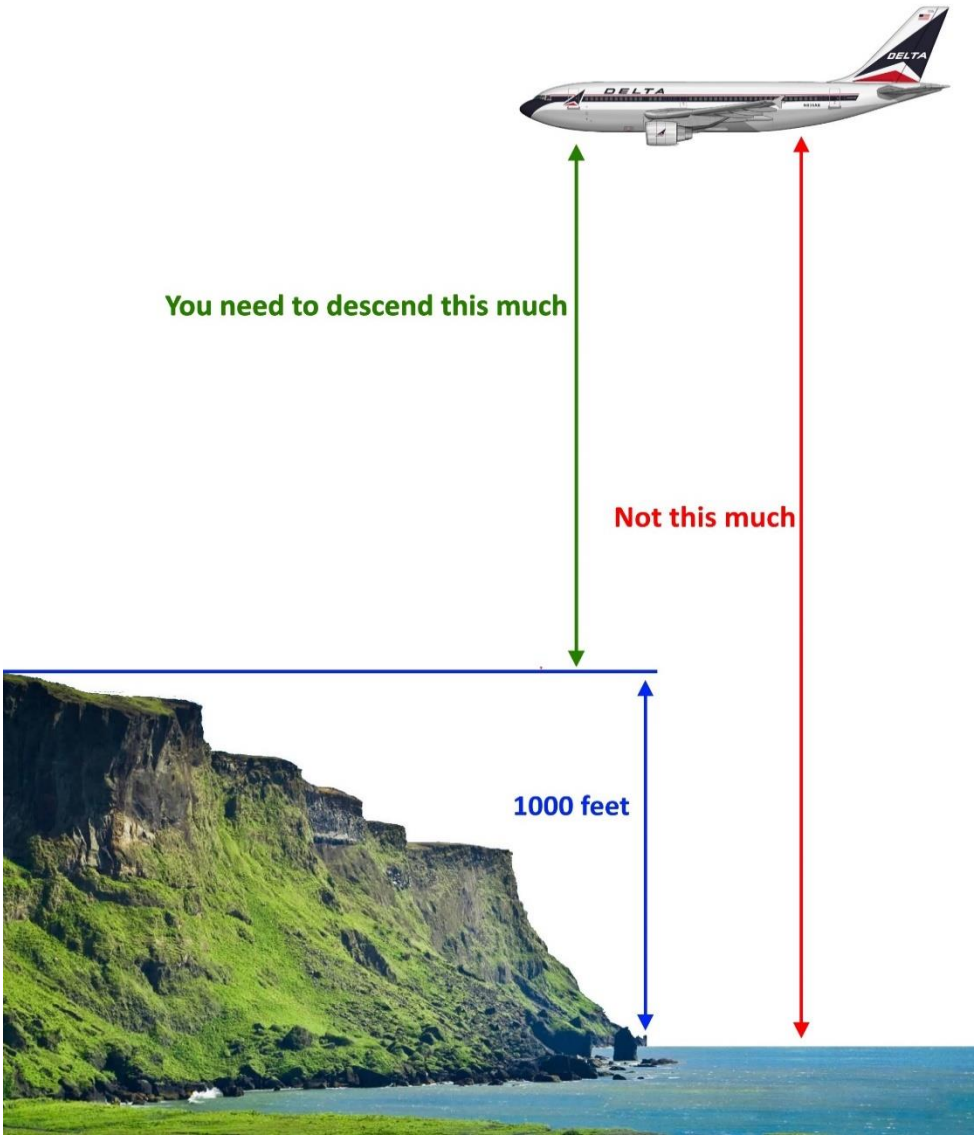
1) How to calculate the point of descent i.e. TOD that matches a 3° profile?

2) How to determine the required rate of descent once TOD is reached?

3) How to maintain a 3° profile during descent?

Calculating the TOD (Top of Descent)

First thing we need to know is the height that we need to lose. For example, if we want to descend from 30,000 feet to a runway that is located at sea level, then we need to lose 30,000 feet during our descent and approach.



However, if the runway is 1000 feet above sea level then we need to lose less height because runway is already closer to us in this case by 1000 feet. That makes it 30,000 – 1000 = 29,0000 feet.

Next step is to use the rule of 3 as discussed above to determine at what distance from the runway we need to start descending. However, we will not be using trigonometry this time because that's not practical (though accurate). Sometimes practicality is preferred to accuracy.

To do it mentally, strip of all the zeroes from the height and multiply the figure by 3.

So if we want to descend from 30,000 feet to a field that is 1000 feet above sea level, all we do is:

29~~000~~ = 29

29 x 3 = 87

i.e. at 87 track miles from touchdown if you start your descent, you will be following a 3º profile. Let's check what our TOD would be if trigonometry is used.

Height = 29000, Descent angle = 3º, Distance = D.

Tan 3 = 29000 / D

D = 29000 / Tan 3

Since we need the distance in nautical miles, we will convert height in feet to nautical miles i.e. 29000 / 6076 = 4.77 nm.

D = 4.77 / 0.052 = 91.7 nm

So you see not much difference (87 vs 91.7). It's not worth using a calculator for this. Some documents mention the division method instead of multiplication. In that case you just strip the last two zeroes and divide the height by 3. Considering the same example:

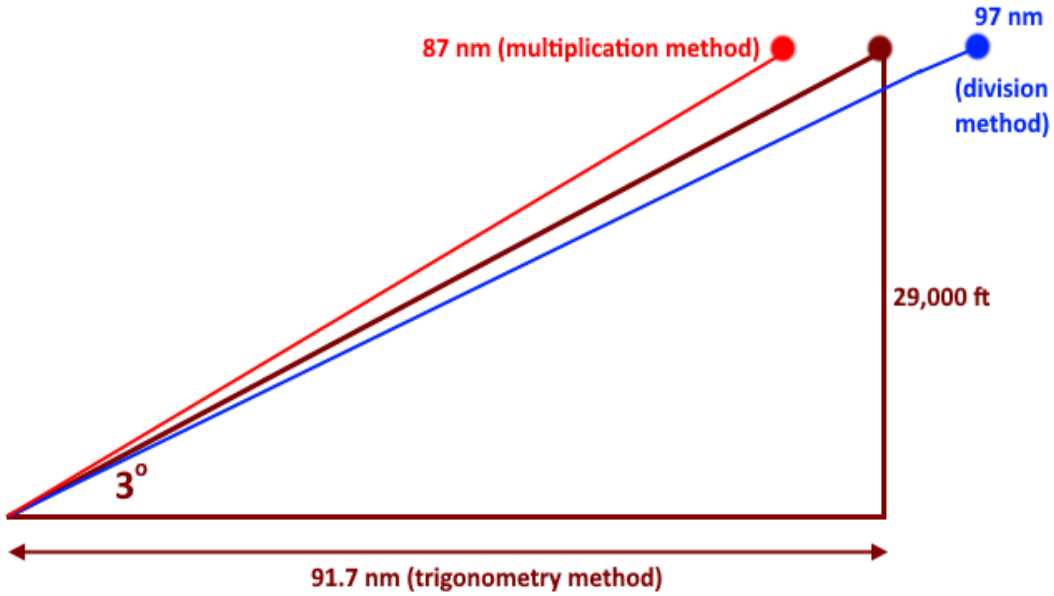
290~~00~~ = 290

290 / 3 = 97 nm.

Again not much difference. The only difference is that the multiplication method delays your TOD by a few miles while the division method makes it earlier.

You can choose any method you like keeping in mind their pros and cons.

If multiplication method is easier in reference to mental math, then division method makes you descend a little early and keeps you slightly below the profile, which ultimately prevents profile deviation during speed reduction.



Once we have determined the TOD distance we need to be aware of two factors that will affect this. These are:

- Distance required to reduce from descent speed to approach speed.
- Head wind or tail wind component.

Let's take them up one by one and see how they affect the TOD distance.

Speed Reduction

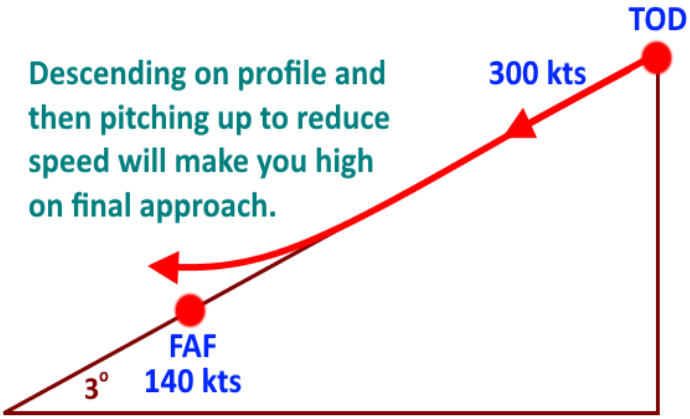
Let's say your normal descent speed is 300 knots and your final approach speed is 140 knots which you have to maintain at FAF (Final Approach Fix).

That means during descent and approach you have to bleed off about 160 knots.

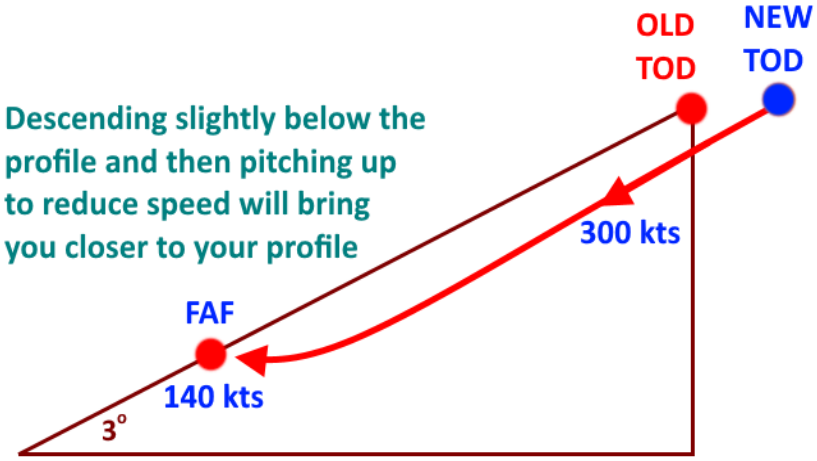
Considering speed brakes are not available, speed can be changed with either Pitch or Power.

In a descent your power levers are already at idle. So the only option left is to pitch up to reduce speed.

If you are exactly on the profile, then pitching up will make you deviate from the profile, and by the time your approach speed is reached you will end up high on your final approach.



In order to avoid this from happening it is desired to stay a little below the profile so that when you pitch up to reduce speed, you start coming closer to your profile, and by the time your approach speed is reached, you are exactly on your profile with correct speed.



Looking at the figure on the right we see that in order to remain slightly below the profile we need to descend a little earlier. If you remember, the division method makes you descend a little earlier and that's its advantage over the multiplication method.

To cater for speed reduction, all you need to do is to add some distance to the original calculated TOD.

But how much?

The answer cannot be a specific single value for all airplanes as they all have different deceleration characteristics, considering their aerodynamics and different weights. However, as a rule of thumb, 1 nm for a speed reduction of 10 knots is a reasonable value to start with. Later on you can adjust this value on the basis of your particular airplane deceleration characteristics and your TOD calculation method.

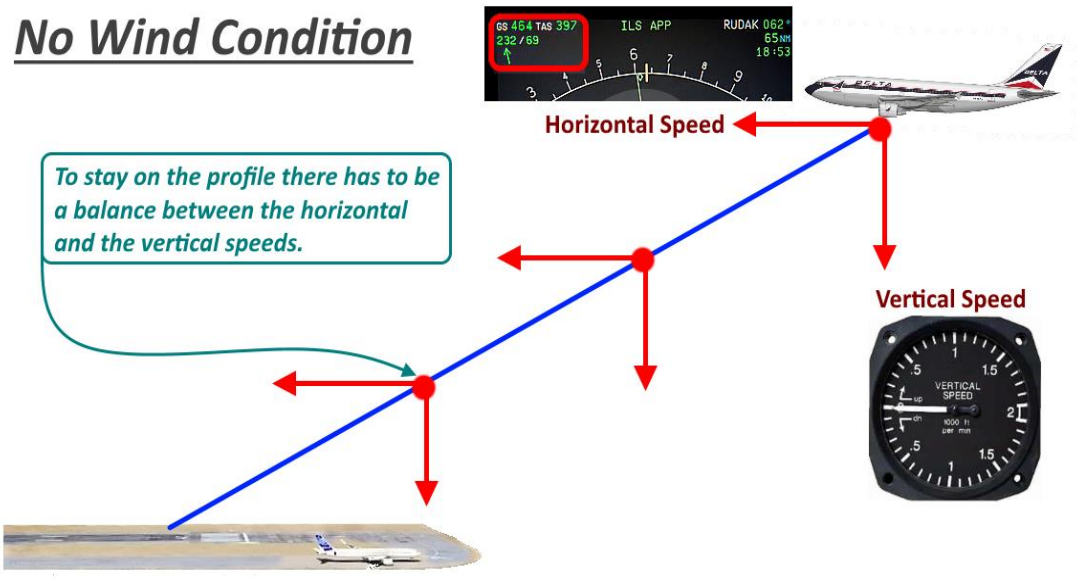
Wind Effect

The other factor that affects the descent profile and in turn the TOD is the wind.

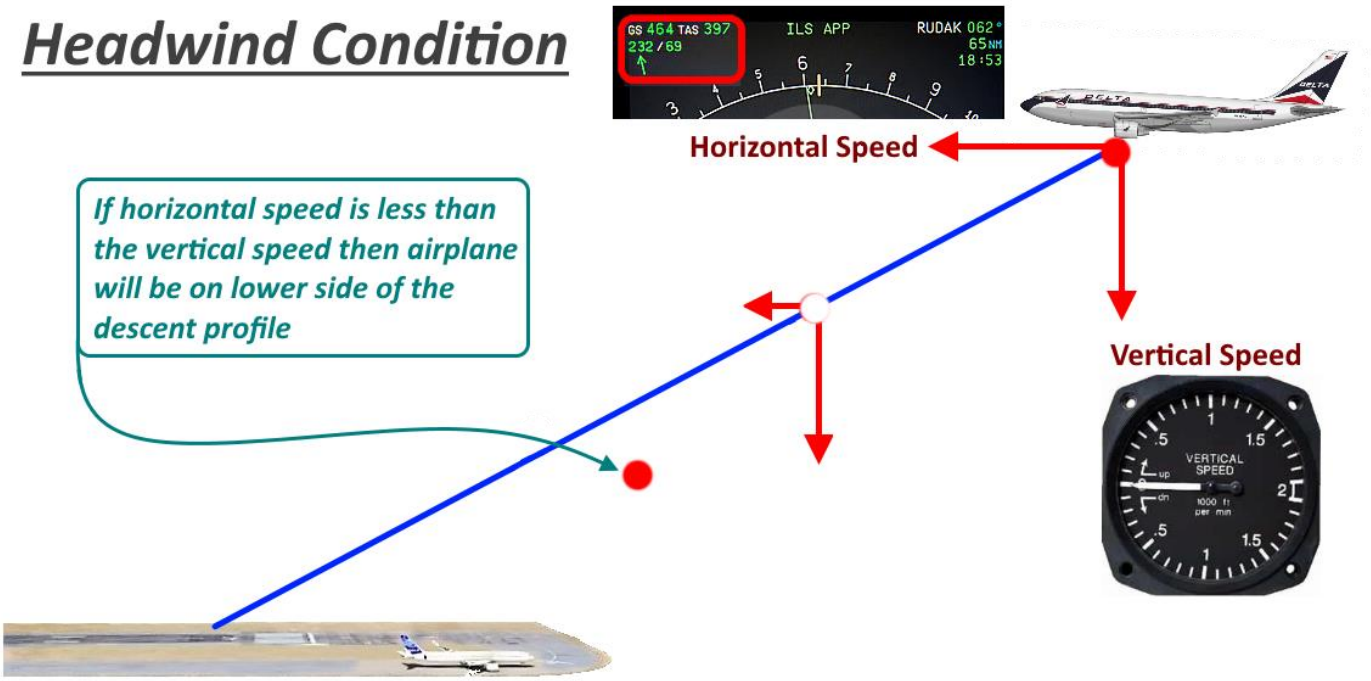
While descending the airplane is going vertically down with some speed and horizontally forwards with some speed.

In order to stay on the required profile path there needs to be a balance between the two speeds.

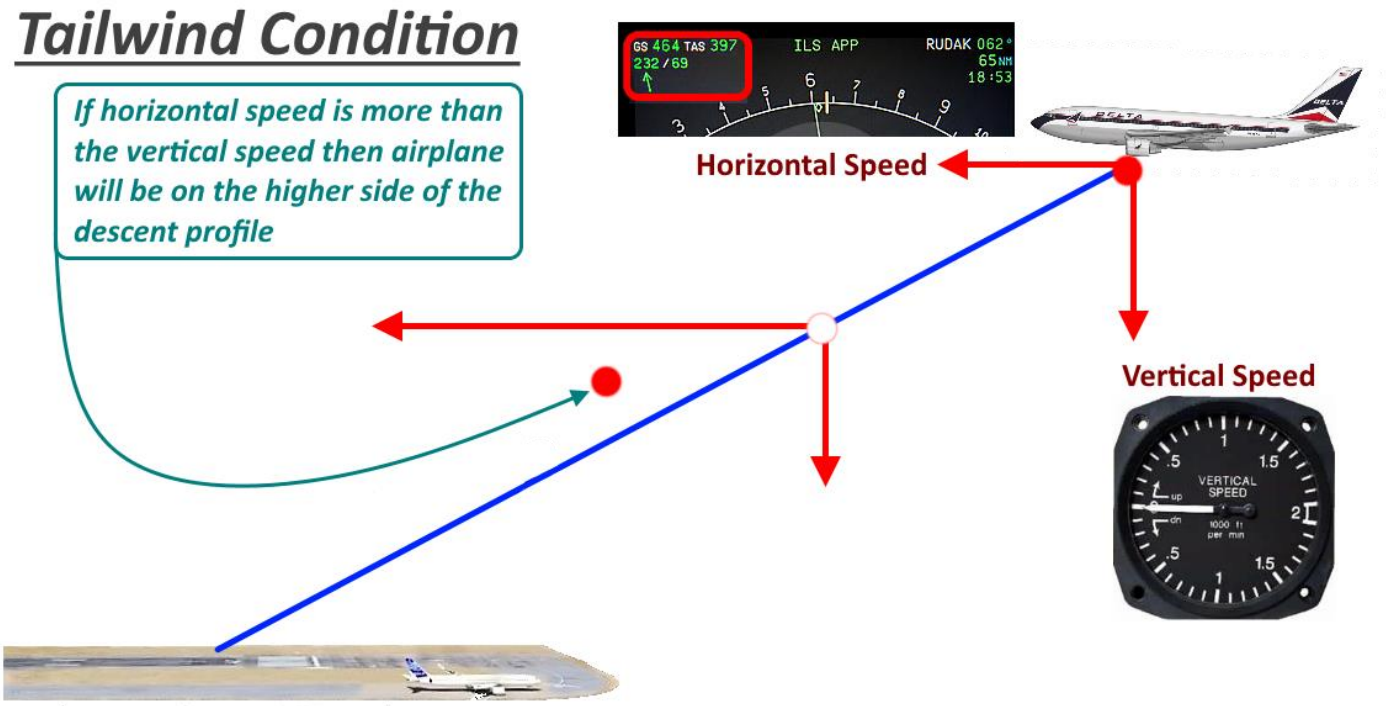
Winds will change the horizontal speed of the airplane.



In case of a headwind the horizontal speed will be reduced. So for a given vertical speed if horizontal speed is reduced then airplane will go down more than going forwards. Therefore, it will end up below the required profile.



In case of a tailwind the horizontal speed will be increased. So for a given vertical speed if horizontal speed is increased then airplane will go forward more than going down. Therefore, it will end up above the required profile.



So to stay on the profile you will have to adjust the rate of descent in relation to the headwind or tailwind component which will change your horizontal speed i.e. your ground speed. High ground speed requires high rate of descent and low ground speed requires lower rate of descent. Therefore, if you are anticipating headwind or tailwind during descent then adjust your TOD distance accordingly.

In case of headwinds we need to delay the descent, so subtract some distance from original TOD distance to get a new distance which is later than the original one.

In case of tailwinds we need to descend early, so add some distance to original TOD distance to get a new distance that is earlier than the original one.

Again the question is how much to add or subtract? Generally, as a rule of thumb, 1nm per 10 knots of head or tail wind is a reasonable figure. Some documents mention 1/3rd of headwind or tailwind component but personally I find it a bit too conservative.

Reviewing TOD Distance Calculation

1) A = (Flight Level – Elevation) x 3

   e.g. (30,000 – 1000) x 3 = 87 nm.

2) B = A + (1nm per 10 knots of speed reduction).

   For reduction of 100 knots, we add 10 nm to 87 to make our TOD distance 97 nm.

3) C = B +/- (1nm per 10 knots of headwind or tailwind component).

   For a 50 knot headwind, we subtract 5 nm from 97 to make our TOD distance 92 nm.

   For a 70 knot tailwind, we add 7 nm to 97 to make our TOD distance 104 nm.

Now that we have answered the first question i.e. how to calculate TOD that matches a 3º profile and when to start the descent, our next question was how to determine the required rate of descent once TOD is reached.

Determining the Required Rate of Descent

As discussed above, descent angle is a function of speed and rate of descent. A correct rate of descent (in feet per minute) must be flown to maintain the 3º profile. The variable is ground speed. Ground speed is the airspeed of the aircraft in knots, plus or minus the headwind or tailwind component.

Since pilots don't fly with calculators in their lap, we will not use trigonometry for this and will rely on mental math. A rule of thumb is to multiply ground speed by 5 to get the required rate of descent in feet per minute e.g. an airplane with a ground speed of 300 knots must descend at (300 x 5) 1500 feet per minute to maintain a 3º profile.

What if the ground speed was 283 knots? No, you don't need to grab a calculator. Just take the first two digits and divide it by 2 i.e. 28 / 2 = 14. Your required rate of descent will be 1400 feet per minute (*can't be 140 because even at 100 knots it will be 100 x 5 = 500 fpm*).

For those who are still wondering where this 5 came into the picture, here is the math behind it:

Rate of Descent = Ground Speed/60 x Glide angle/60 x 6076.

For a 3º slope and assuming 6000 feet in a nautical mile the formula can be simplified to:

$$\frac{GS \times 3 \times 6000}{60 \times 60} = \frac{GS \times 18000}{3600} = GS \times 5$$

For math junkies who want to cross check the answer with trigonometry, here it is:

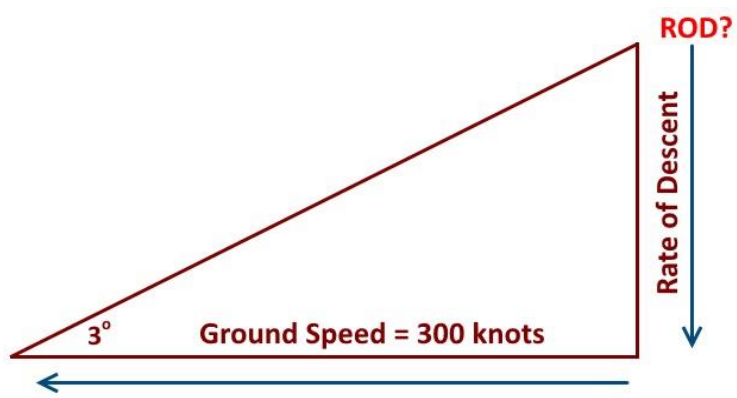
Tan 3 = ROD / 300

ROD = Tan 3 x 300

ROD = 15.72 nm / hour

ROD = 15.72 / 60 = 0.262 nm / min

ROD = 0.262 x 6076 = 1592 feet / min



Now finally coming to the last question about maintaining the 3º profile, once the descent has begun.

Maintaining a 3º Profile Descent

Once the airplane is in a descent we need to constantly check whether it is on the required descent profile or not. Winds may not be the same. Change in winds will change the ground speed. If vertical speed i.e. rate of descent is not adjusted in accordance with the new ground speed, then the airplane will deviate from the required profile.

Let's say you are 40 track miles short of landing and you want to check if you are on your profile on or not. Your calculations will not start when you are exactly 40 track miles short of landing. The calculations will be done in anticipation before reaching this point so that you already have some value to compare. Let's say you do your calculations at 50 track miles and come up with a value. When you reach 40 track miles you compare the calculated values which signify where you should be and where you actually are on the profile. After comparison if you figure out that you are not on the profile, you will have to adjust your rate of descent.

Now let's talk about the calculations involved. At 40 track miles you should be:

Rule of 3 again, 40 x 3 = 120

Add two zeroes i.e. 12000 feet

However, there are two factors that need to be taken care of. As discussed earlier they are:

- Field Elevation
- Speed Reduction

Let's reflect upon these factors by considering different scenarios.

Scenario 1:

If your landing field is located at sea level then, then you don't need to worry about the field elevation correction. You jump on to the next one i.e. speed correction. If your speed is already low and deceleration is not required, then you can forget about this correction also. In this scenario at 40 track miles you should be at (40 x 3 = 120 + 00) 12,000 feet.

Scenario 2:

Scenario 1 is rare. Normally you will descend at a speed which you will have to reduce when approaching the terminal area, and your field elevation will not always be at sea level. So you will need to cater for these two factors. Let's say you are descending at a speed of 300 knots and your field elevation is 1000 feet above sea level. At 40 track miles you should be at:

40 x 3 = 12,000 feet above the field (and not sea).

So 12,000 + Field Elevation of 1000 = 13,000 feet (on altimeter based on QNH setting).

Remember the height you calculate has to be above the field and not sea, as mentioned in the beginning of this article. Your altimeter (if you have set QNH) is measuring height from the sea and not the field. So field elevation will always be added to your basic rule of 3 calculation. This is easy to remember because the word elevate itself means raising or lifting up.

Having done the field elevation correction, you now have to cater for speed reduction. As discussed earlier, descending slightly below the profile gives you the advantage of coming close to the required profile when you are decreasing speed.

How much below the profile will depend on aircraft type and mass, since every airplane has its own aerodynamic deceleration characteristics (along with drag devices) and momentum. e.g. a big and heavy (340 tons) B777 has to be roughly 3000 to 4000 feet below the profile to cater for speed reduction whereas a smaller ATR will be easily manageable even if flown only 500 feet below the profile. So depending on the aircraft type and pilot skills, the value can be anywhere from 500 to 1000 or 2000 or 3000 etc. You will find this out during line training on your specific aircraft. Then with experience you can modify this value to suit yourself. For the sake of this article we will take the value of 1000 feet and will call it the "Deceleration Value".

Coming back to our example, at 40 track miles after applying elevation correction we determined a value of 13,000 feet. Since for speed reduction we need to be 1000 feet below this, we need to be at:

13,000 – 1000 = 12,000 feet.

So if at 40 track miles we are passing 12,000 feet, our descent profile is correct. As mentioned above we would calculate this before reaching 40 track miles. So when the distance is 40 track miles we will just look at the altimeter and see what level are we passing through. This will give us an idea if we are getting high or low on the profile. Accordingly, we will have to adjust our rate of descent.

Let's say instead of 12,000 feet we were passing through 13,000 feet at 40 track miles. This means we are high. To correct, have a look at your ground speed. If it is 300 knots, then (300 x 5) 1500 feet per minute is required to be on the profile. Since we are high we need to increase our rate of descent beyond 1500.

On the other hand, if we were passing through 11,000 feet instead of 12,000 then we are getting low. If ground speed in this case was 280 then 1400 feet per minute is required to be on the profile, so we need to reduce our rate of descent to value less than 1400.

After applying the required correction, we will check again after 10 miles (i.e. at 30 miles according to this example if rate of descent was adjusted at 40 track miles) to see if we are coming back to our profile or not.

Instead of doing a two-step procedure i.e. first adding for elevation and then subtracting for speed reduction we can simplify it and make it a one-step procedure to reduce our mental workload. Since we know before our descent, the elevation and deceleration value, we can use a simple formula before descent to determine a single value for elevation and speed adjustment that can be compared at profile check points. Let's call this ESA value i.e. Elevation Speed Adjustment value:

ESA = Elevation – Deceleration Value

According to scenario 2 (where elevation = 1000 and deceleration value = 1000) this will be:

ESA = 1000 – 1000 = 0

An ESA of 0 means that the answer 12000 we get by multiplying 40 x 3 needs no adjustment. Therefore, at 40 track miles, we need to be at 40 x 3 = 12,000 feet. And this is what we determined above while doing the two step procedure.

On the basis of this simple formula let's practice some more scenarios, assuming we need to check at 40 track miles.

Scenario 3:

Elevation = 0

Deceleration Value = 1000

ESA = 0 – 1000 = -1000

At 40 track miles, 40 x 3 = 12000

Since ESA in this case is -1000, we need to adjust 12000

12000 – 1000 = 11,000

Therefore, we need to be at 11,000 feet at 40 track miles in this case.

Scenario 4:

Elevation = 2000

Deceleration Value = 1000

ESA = 2000 – 1000 = 1000

At 40 track miles, 40 x 3 = 12000

Since ESA in this case is +1000, we need to adjust 12000

12000 + 1000 = 13,000

Therefore, we need to be at 13,000 feet at 40 track miles in this case.

In case you find the formula confusing, just follow the two step procedure mentioned above.

You'll soon find out what's going on!

Scenario 5:

If in your descent path, there is a waypoint that has an "At or Above" height restriction then you'll have to cater for it in a way that you don't go below it. Generally, you follow the VNAV for profiles that have waypoints with speed and height constraints, however if you want to do it manually then just consider that waypoint as your field elevation and rest remains the same e.g. If a waypoint says at or above 5000 feet and your track miles to that waypoint are 20, then:

20 x 3 = 6000

6000 + 5000 = 11,000

That means if you are at 11,000 feet and 20 track miles from a waypoint that has an "at or above" restriction of 5000, you are on the correct profile and will meet the restriction comfortably.

Keep Updating the FMC

FMC track miles are based on whatever route is put in it. During approach, ATC generally vectors you for landing and your routing is not exactly according to what you've put in the FMC i.e. the STAR and transition you've selected. That means if your FMC route is 25 nm and your ATC vectored route is 15 nm, there is an error of 10 nm. If you do not modify your FMC route with the actual route you are following, then you would not get the correct track miles for your calculation.

So always update the FMC route according to what you are actually flying. Once you have flown to an airfield two or three times, you generally come to know what routing ATC will make you fly. So once on vectors, modify the FMC accordingly.

If it's your first time to an airfield and you don't know what routing you will be following on vectors, then simply request your estimated track miles from ATC. Professional ATC personnel always tell you your track miles (without asking) when they put you on vectors.

OVERVIEW

1) Calculate Top of Descent Distance

I. A = (Flight Level – Elevation) x 3

e.g. (30,000 – 1000) x 3 = 87 nm.

II. B = A + (1nm per 10 knots of speed reduction).

For reduction of 100 knots, we add 10 nm to 87 to make our TOD distance 97 nm.

III. C = B +/- (1nm per 10 knots of headwind or tailwind component).

For a 50 knot headwind, we subtract 5 nm from 97 to make our TOD distance 92 nm.

For a 70 knot tailwind, we add 7 nm to 97 to make our TOD distance 104 nm.

2) Calculate Required Rate of Descent

I. Ground Speed x 5

e.g. 300 x 5 = 1500 feet per minute or 30/2 = 15 + 00 = 1500 feet per minute

3) Keep Checking your Profile during Descent

I. Track Miles x 3

e.g. 40 x 3 = 120 + 00 = 12,000 feet

II. Elevate for Field Elevation

e.g. 12,000 + 2000 = 14,000 feet

III. Reduce for Speed Reduction

e.g. 14,000 - 1000 = 13,000 feet

Was this document helpful? Click here to Answer!

Disclaimer: ***"Managing a Descent Profile" is a personal perspective of the undersigned. It does not sanction any pilot to violate his/her Company's Standard Operating Procedures, Aircraft Manuals or Manufacturer's Recommendations.***

K. Haroon